FRICTION STIR WELDING OF AA6061& AA5052 ALUMINUM ALLOYS IN-SITU ANALYSIS WITH ATMOSPHERIC AIR AND UNDERWATER CONDITION

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Abstract
In this research AA6061 & AA5052 aluminum alloys are widely used for fabrication of lightweight structures requiring a high strength to weight ratio in aerospace, naval, rail and automotive industries. As compared to the traditional fusion welding processes which are commonly used for joining structural aluminum alloys, friction stir welding (FSW) process is an emerging solid-state joining process in which the material that is being welded does not melt and recast. In this research work, an experimental investigation is to analyze the effect of welding parameters such as welding speed, tool tilt angle, and tool rotational speed on welding strength. The experimental work is carried out between a normal condition or air condition and underwater condition. In the test, it is found that the UWFAW joint fabricated using tool rotational speed of 1400 rpm yielded higher tensile strength 185 MPa. Welding at 1400 rpm tool speed, 20mm/min welding speed & 0degree tool tilt angle. Finally, the results are compared in this work with the tool speed& twilit angle is constant in these two conditions. The properties of mechanical and microstructure ware studied.
Keywords: Aluminum Alloys AA6061& AA5052; Friction Stir Welding (FSW); Atmospheric and Underwater Condition.

I. INTRODUCTION

Alloy 6061 is one of the most widely used in the 6000 series. This standard structural alloy one of the most versatile of the heat treatable alloys is popular for medium to high strength requirements and has good toughness edge characteristics [1-2]. It has an excellent corrosion resistance to seawater and also it's easily welded joined by various commercial methods. Since 6061 is heat treatable alloy strength in its condition can be reduced in the weld region. Selection of an appropriate filler alloy will depend on the desired weld characteristics. 6061 aluminum properties include its structural strength and toughness [3]. It also offers good finishing characteristics and responds well to anodizing, including clear, clear and color dye, and hard coat. 6061 aluminum alloy is also easily welded and joined [4]. However, in its condition, the welds may lose some strength, which can be restored by re-heat-treating and artificially aging. 5052 is an aluminum alloy, primarily alloyed with magnesium and chromium. Typical applications include architecture, general sheet metal work, heat exchangers [5]. This material has very good weldability at arc and resistance welding conditions.

II. MATERIALS AND METHODS

AA6061& AA5052 has good creep resistance and is a medium strength alloy. This alloy is ideal for high integrity casting operating at ambient temperatures or up to 300^{o}F.The casting will contain minimal microporosity and the tendency to hot cracking is low. Castings are pressure tight and weldable.

Table.1 Chemical composition of AA6061

Alloy	Al	Cr	Cu	Fe	Mg	Mn	Zn
Wt %	97.67	0.064	0.19	0.25	0.8	0.12	0.11

Table.2 Mechanical properties of AA6061

Alloy	Yield strength(Mpa)	Ultimate Tensile Strength (Mpa)	% Elongation	Hardness
AA6061	144	239	14	65 HV

Table.3 Chemical composition of AA5052

Alloy	Al	Cr	Cu	Ir	Mg	Mn	Zn
Wt%	95.7-97.7	0.15-0.35	0.1	0.4	2.2-2.8	0.1	0.1

Table.4 Mechanical properties of AA5052

Alloy	Yield strength(MPa)	Ultimate Tensile Strength (MPa)	% Elongation	Hardness
AA5052	193	228	12	68 HV

Friction stir welding tool design and fabrication: The initial FSW tool designed was a simple cylindrical tool with 18 mm shoulder diameter, diameter, and height of the pin equal to the thickness of the sheets processed i.e., 5 mm. Tool shoulders are designed to produce heat (through friction and material deformation) to the surface and subsurface regions of the workpiece.

Table .5 Mechanical and physical properties of H13 tool steel

Tensile strength	Yield stren-gth	Elonga-tion	Hardness (VHN)	Elastic modulus	Density
1990 MPa	1650 MPa	9%	549 HV	190-210 GPa	7.76 g/ cm^3

Fig .1 H13 tool steel Dia. 18 mm × 100 mm.

Table.6 Chemical Composition of H13 tool steel

Element	Composition %
C	0.35
Mn	0.3
Si	0.88
Cr	5.0
Ni	0.3
Mo	1.5
V	1.0
Cu	0.25
P	0.03
S	0.03
Fe	balance

Table .7 FSW tool dimensions used in experiments.

Type of tool	Shoulder diameter (mm)	Pin diameter (mm)	Pin length (mm)
Threaded cylindrical tool	18	5	4.7

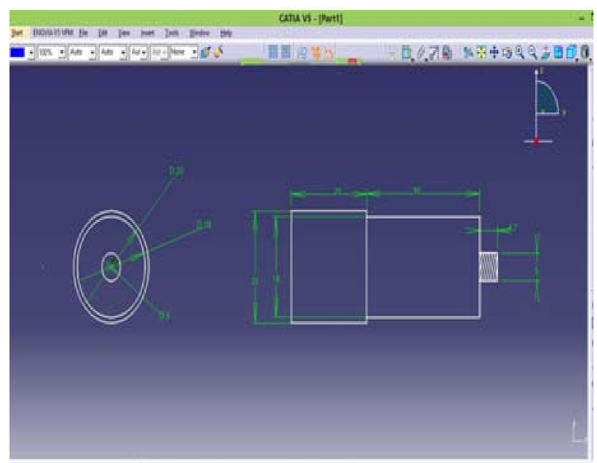

Fig .2 Threaded tool design by CATIA

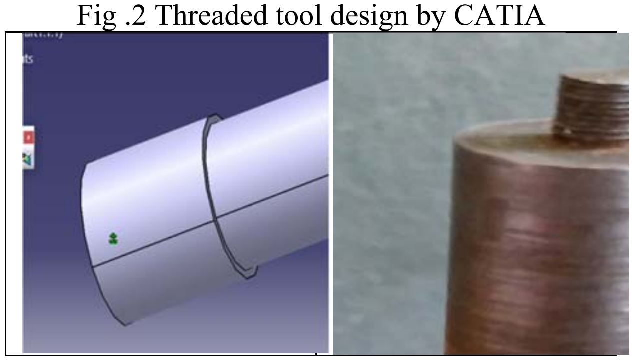

Fig .3 Threaded tool design and its photographs

A) Weld procedure

A Vertical Milling Machine was used for friction stir welding (FSW) of AA6061 & AA5052. The machine was a maximum speed of 3000 rpm and 1-horsepower. The experiments were conducted on the AA6061 & AA5052.

- Before the friction stir welding, the weld surface of the base material was cleaned.
- The Aluminium plates of size 150×60×4mm are fixed in the fixture and placed on the machine bed.
- Processing began at prescribed spindle speed and travel rate as the downward force is kept constant.
- At that speed, the tool will complete the friction stir welding in the forward direction on the front side of the plates.
- These plates are removed another two Aluminium plates replaced in the fixture.
- At that same speed, the tool will complete the friction stir welding on both (front and rear) sides of the Aluminium plates.

In the present work, the influence tool tilt angle on the performance of FSW such as Hardness and tensile strength is evaluated under different experimental conditions.

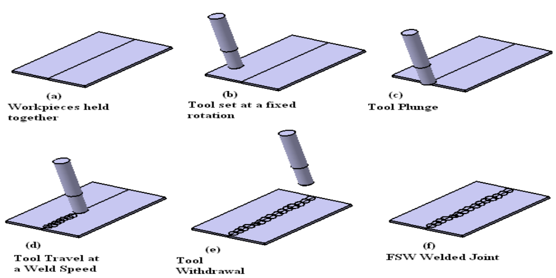

Fig .5 Sequence of operation

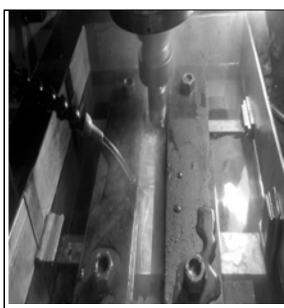

Table .8 Process parameter values & their levels

Condition & Specimen number	Tool rotational speed (rpm)	Welding speed (mm/min)	Tool tilt angle (degrees)
AC 1	710	20	0
AC 2	900	20	0
AC 3	1120	20	0
AC 4	1400	20	0
WC 5	710	20	0
WC 6	900	20	0
WC 7	1120	20	0
WC 8	1400	20	0

Graph .1 Weld distance Vs. Hardness AC

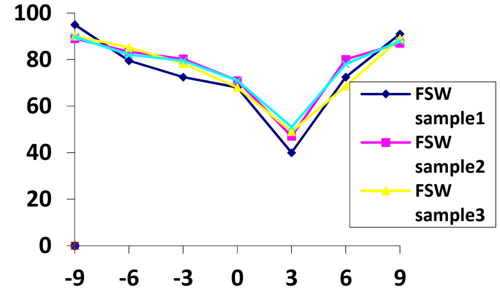

Table 9 Vickers hardness values at various distances from weld nugget center

FSW Sample & Condition	-9	-6	-3	0	3	6	9
	AA5052 Advancing Side			Center	AA6061Retriving Side		
WC 1	79	69	50.3	45.3	41	65	75.7
WC 2	85.9	71.7	55.3	45	43	69.4	84.2
WC 3	89.9	78.7	69.2	45.7	49	78.9	90
WC 4	93	81	73.7	49.9	52	80	92

III. RESULTS&DISCUSSION

The Vickers Hardness Number, tensile strength and impact strength of friction stir weldments of AA6061 & AA5052 at various tool Speeds, tool feed& tool tilt angle are tabulated in table and graph is drawn.

Table 10 Vickers hardness values at various distances from weld nugget center

FSW Sample & Condition	-9	-6	-3	0	3	6	9
	AA5052 Advancing Side			**Center**	**AA6061Retriving Side**		
AC 1	95	79.6	72.5	68	40	72.5	91
AC 2	89	83.4	80.3	71	47	80.1	87
AC 3	90.1	85.2	78.3	68	49	68.5	89
AC 4	89.7	82.1	79.5	71	51	78	88

Table 11 Tensile test results

Specimen Details	**Yield Strength in MPa**	**Tensile Strength in MPa**	**Elongation in mm**
WC 710	102	117	2.37
WC 900	162	175	5.51
WC 1120	175	181	5.06
WC 1400	183	185	5.5
AC 710	55	59	2.4
AC 900	155	167	4.46
AC 1120	153	159	3.51
AC 1400	149	170	5.23

Graph .2 Tensile test stress Vs strain

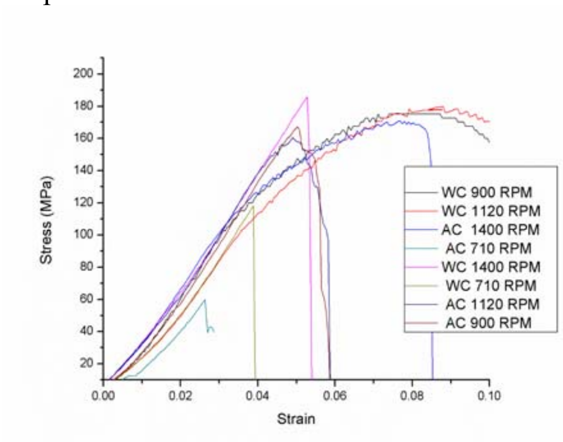

Table .12 Weld sample Vs Impact energy (J)

Weld sample	**Impact energy(J)**
AC 1	13
AC 2	15
AC 3	20
AC 4	8
WC 5	18
WC 6	19
WC 7	10
WC 8	8

Graph .4 Weld axis to Impact strength

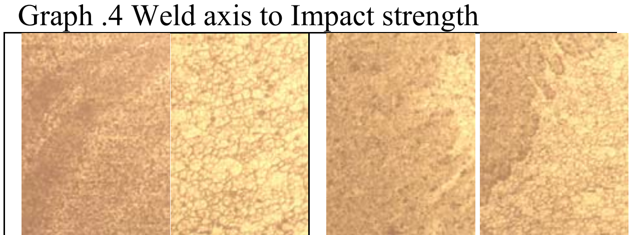

Fig. 7 Microstructures at the different zones of the welded Sample 1400 rpm for two condition a)Weld region of Sample 1400 rpm under AC(b)Weld region ofSample1400 rpm under WC (c)Interface in Sample 1400 rpm under AC (d)Interface in Sample1400 rpm under WC

IV. CONCLUSIONS

a) Friction stir welds between AA5052 and AA6061 Al alloys sounds promising, having demonstrated excellent weldability and performance characteristics.

b) The cylindrical threaded pin has rendered excellent bondage between both alloys (AA5052 and AA6061) by effective friction stir joining.

c) Both the conditions have exhibited nearly equal ultimate strength but in UWFSW have more tensile strength properties compared to FSW.

d) The extensive microstructural study gives a better understanding of the grain structures and their influence on mechanical properties.

e) The mechanical and metallurgical characterizations have shown good agreement which is clearly evident from results obtained.

REFERENCES

[1].Mishraa,R.S.,Mab,Z.Y.,2005.Frictionstirweldingandprocessing,MaterialsScienceandEngineeringR50,p1-78.

[2].Shigematsu,I.,Kwon,Y.J.,Suzuki,K.,Imai,T., Saito,N.,2003.Joiningof5083and6061aluminum alloysbyfrictionstirwelding,JournalofMaterialScienceLetters 22(5),p. 353−356.

[3].Dawes,C.J.,Thomas,W.M.,1996.Frictionstir processweldaluminiumalloys,WeldingJournal75 (3),p.41–5.

[4].Thomas,W.M.,Nicholas,E.D.,1997.Frictionstirweldingforthetransportationindustries,Materials&DesignVol. 18,p.269-273.

[5].Kumbhar,N.T.,Sahoo,S.K.,Samajdar,I.,Dey, G.K.,Bhanumurthy,K.,2011.Microstructureand microtexturalstudiesoffrictionstirweldedaluminiumalloy5052,Materialsand Design 32,p. 16571666.

[6].ThreadgillPL, LeonardAJ, ShercliffHR, WithersPJ.Frictionstirweldingofaluminumalloys .IntMaterRev2009;54:49–93.

[7]. Liang XP,LiHZ,LiZ,Hong T,MaB,LiuSD,etal.Study onthe microstructure inafrictionstirwelded2519T87Alalloy.MaterDes 2012;35:603–8.

[8]. W.M.Thomas, E.D.Nicholas, J.C.Needham, M.G.Murch, P.Templesmith, and C.J.Dawes, G.B.Patent 9125978.8, Dec 1991

[9]. C.Dawes and W. Thomas, TWI Bull., Vol 6, Nov/Dec 1995, p 124

[10]. B.London, M.Mahoney, B.Bingel, M.Calabrese, and D.Waldron, in proceedings of the Third Int. Symposium on Friction Stir Welding, Sept 27-28, 2001 (Kobe, Japan).

[11]. C.G.Rhodes, M.W.Mahoney, W.H.Bingel, R.A.Spurling, and C.C.Bampton, Scr.Mater, Vol 36, 1997,p 69

[12]. G.Liu, L.E.Murr, C.S.Niou,J.C.Mcclure, and F.R.Vega, Scr.Mater., Vol 37, 1997, p355

[13]. K.V.Jata and S.L.Semiatin, Scr.Mater, Vol 43, 2000, p743.

[14]. S.Benavides, Y.Li, L.E.Murr, D.Brown, and J.C.McClure, Scr,Mater,Vol 41, 1999, p809.

[15]. H.B.Cary, Modern welding technology, Prentice Hall

[16]. C.J.Dawes and W.M.Thomas, Weld.j.,Vol 75, 1996,p 41.